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Lab. Project 5319-39
Final Report

From: Commander, New York Naval Shipyard
To: Distribution List

18 FEB 1963

Subj: Atmospheric Contamination from Selenium Rectifiers SF-013-12-09

Ref:
(a) BUSHIPS ltr F013-12-09 Ser 660E-21856 of 11 Aug 1960
(b) NAVSHIPYDNYK Lab. Project 5319-39 Progress Report 1 of 29 Nov 1961
(c) NAVSHIPYDNYK Lab. Project 5319-39 Progress Report 2 of 2 Mar 1962
(d) NAVSHIPYDNYK Lab. Project 5319-39 Progress Report 3 of 4 Dec 1962
(e) BUSHIPS ltr F013-12-09 Ser 660E-2374 of 25 May 1962
(f) BUMED ltr 73-jp of 4 Jun 1962
(g) Drinker, P. and Nelson, K.W., Arch. of Ind. Hyg. and Occ. Med., 8, p 185-9, 1953

Encl:
(1) Selenium Contamination After Rectifier Burnout - Tabulation of Data
(2) Plots of Selenium Atmospheric Contamination VS Time After Rectifier Burnout
(3) Photo No. 19459 - Selenium Rectifier After Burnout
(4) Summary Data of Selenium Concentrations on Burnout

1. Reference (a) authorized the Material Laboratory to investigate selenium contamination of air produced by electrical loading and burnout of selenium rectifiers in shipboard electrical and electronic equipment. Surveillance of the atmosphere on selected ships was accomplished by means of a continuous air sampling apparatus, the Gelman Sequential Sampler, which automatically collects air samples both particulate and gaseous for subsequent analysis. The samples were analyzed for selenium at the Material Laboratory by spectrofluorometric procedure. Data reported in reference (c) from the electronic countermeasure room of the USS KEPLAR (FRAM) DDE-765 indicated a selenium concentration of approximately 0.001 µg/liter. Reference (d) reported data obtained on atmospheric sampling of the USS NAUTILUS, SSN-571, where total selenium values were 0.8 to 2.0×10^{-3} µg/liter. Particulate samples collected by The Taft Engineering Center in various F.B.M. submarines were analyzed by the Laboratory for selenium by neutron activation, where total selenium values of 0.03 to 0.9×10^{-3} µg/liter were obtained. The atmosphere of a 500 cu. ft. room at the Laboratory was monitored, wherein a total of 25 selenium rectifiers under dynamic aging tests at 50°C with very little circulation of air, gave values of 0.21 to 0.90×10^{-3} µg/liter, reference (b). The exceedingly low values obtained from atmospheric monitoring of Naval Ships and from laboratory experiments were approximately 10^4 times lower than the Bureau of Medicine and Surgery revised maximum permissible concentration for selenium of 10 µg/liter, reference (f).

2. It was further pointed out in previous laboratory work, reference (g), that the amount of selenium evolved from electrically burned-out rectifiers is governed by the fabrication process (electroforming etc.) and by the

type of burnout. Thus application of high current burnout (40-50 times rated capacity) at rated voltage overload, produced instantaneous burnout, with moderate evolution of selenium, while intermediate level current (10 times rate capacity) at potential below rated voltage caused a time-lag burnout, with considerably less evolution of selenium.

3. The final phase of this investigation consisted of overload and burnout of a G.E. 6RS5MH98 6" x 4" twelve plate rectifier, rated at 4 amperes D.C. and 312 volts A.C. in a room of approximately 600 cu. ft. with ventilation of 89 cu.ft./min. Sampling of gaseous and particulate atmospheric contaminants was performed at rated load and 150 percent electrical overload and at burnout. Because of the good load carrying characteristics of this rectifier, and power limitations at the Laboratory facility it was necessary to raise the applied voltage to 960 volts AC and a current of 30 amperes rms in a pulsating manner to effect burnout. This sequence consisted of six cycles of energizing for 10 seconds at 5 minute intervals. Since it is not feasible, due to limitations in time, and the undesirability of destroying shipboard equipment to perform this experiment on naval ships, a room at the Material Laboratory was used to simulate shipboard conditions. The atmosphere in the room was monitored and selenium concentrations were determined using the improved microfluorometric procedure.

<u>Results</u>

4. The concentrations of selenium gaseous and particulate contamination produced on burnout of the 6"x4" twelve plate rectifier at the severe electrical loading level of 960 volts A.C. and 30 amperes D.C. are shown in enclosure (1). On burnout, the combined particulate and vapor selenium concentrations, averaged for the first two hours of monitoring, was 0.54×10^{-3} μg/liter. As illustrated in enclosure (2) the gaseous selenium curve shows a rapid exponential drop to background level in approximately four hours. The particulate selenium content descends to a constant level after 8 hours of atmospheric monitoring. The residual value of 0.054×10^{-3} μg/liter of selenium is higher than background and may be due to circulation of selenium dust that deposited on various surfaces in the room on burnout of the rectifier. Analysis of adhesive paper, $6\frac{1}{2} \times 6\frac{1}{2}$ inches which represents particulate fallout placed 2 in. and 24 in. from the rectifier gave values of 0.90×10^{-3} and 0.35×10^{-3} μg/sq. in. respectively for a 20 hour period. A photo of the rectifier after burnout is shown in enclosure (3).

5. The total selenium values obtained were in the range of 0.001 μg/liter which is 10^4 times lower than the recently revised acceptable level of 10 μg/liter as stipulated in reference (f). The selenium concentration level on naval ships such as the USS NAUTILUS, USS KEPLAR and various F.B.M. nuclear submarines were in the same range of approximately 0.001 μg/liter. The maximum values obtained after deliberate burnout of a selenium rectifier at the Laboratory were comparable. This relatively low selenium output was unexpected and may be due to: (a) the very good current and voltage capabilities of this particular rectifier, (b) pulsating or intermittant electrical overload rather than instantaneous burnout. The former type resembling a sustained or slowly increased load is known to produce considerably less contamination than the latter, reference (g).

6. A summary of the data obtained in laboratory studies is presented in enclosure (4). Data reported in reference (g) are included for comparison purposes. For realistic comparison the data of the last column have been corrected to indicate selenium contamination for a 600 cu. ft. (16,800 l) room, interpolating data derived in two instances from small test chambers assuming fairly uniform distribution during the measurement period.

Conclusion

7. Based on the experimental data included in this report of selenium contamination of the atmosphere produced by electrical loading of selenium rectifiers on surface vessels and nuclear submarines, and by loading, overloading and subsequent burnout of selenium rectifiers under both laboratory, static and dynamic ventilation, shipboard simulated conditions, it is concluded that no hazard exists to shipboard personnel other than those responsible for electronic repair or maintenance, regarding selenium contamination of the atmosphere.

Discussion

8. The summary results indicate that without ventilation, the highest selenium value produced in a 600 cu. ft. room by a single 6x4, twelve plate rectifier would be 0.85 μg/liter. Burnout of as many as 12 rectifiers in one area would be required to equal or exceed the 10 μg/liter specified as the maximum permissible concentration. In the event of an accident which would result in the burnout of selenium rectifiers, a respirator mask to screen out the selenium particulate spray, and gloves should be used by personnel involved in the repair of the electronic equipment. Where possible, it would be advantageous to permit settling of selenium dust followed by vacuum cleaning of the equipment in areas adjacent to the rectifier.

Recommendation

9. In view of the relatively non-hazardous, low levels of selenium contamination of the atmosphere resulting from shipboard and laboratory operation of selenium rectifiers, it is recommended that no precautionary changes be made either in the design or the operation of electrical or electronic equipment containing such rectifiers.

In the event of rectifier burnout, it is recommended that routine hygienic measures in the contaminated area be observed for the protection of those personnel engaged in the handling and repair of failed equipment.

E. J. Jehle

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By direction

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Material Laboratory

Lab. Project 5319-39
Final Report
Enclosure (1)

SELENIUM CONTAMINATION AFTER RECTIFIER BURNOUT*

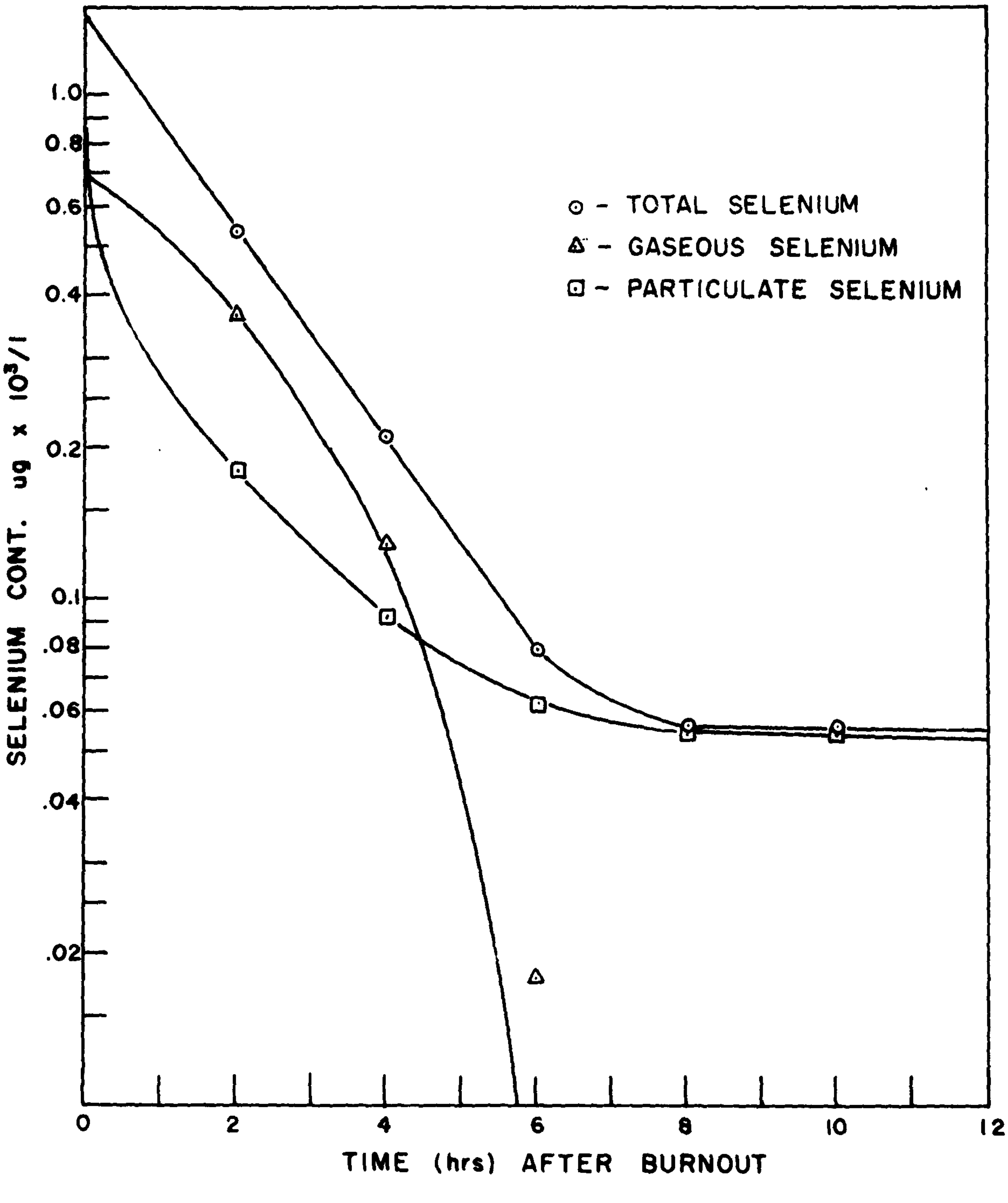
a. Atmospheric

Time (hours)	Gaseous Se Scrubber	Particulate Se Millipore Filter 0.5 Micron	Total
	(μg x 10^{-3}/liter)		
2	0.36	0.18	0.54
4	0.13	0.092	0.22
6	0.017	0.063	0.080
8	<0.002	0.054	0.056
10	<0.002	0.054	0.056

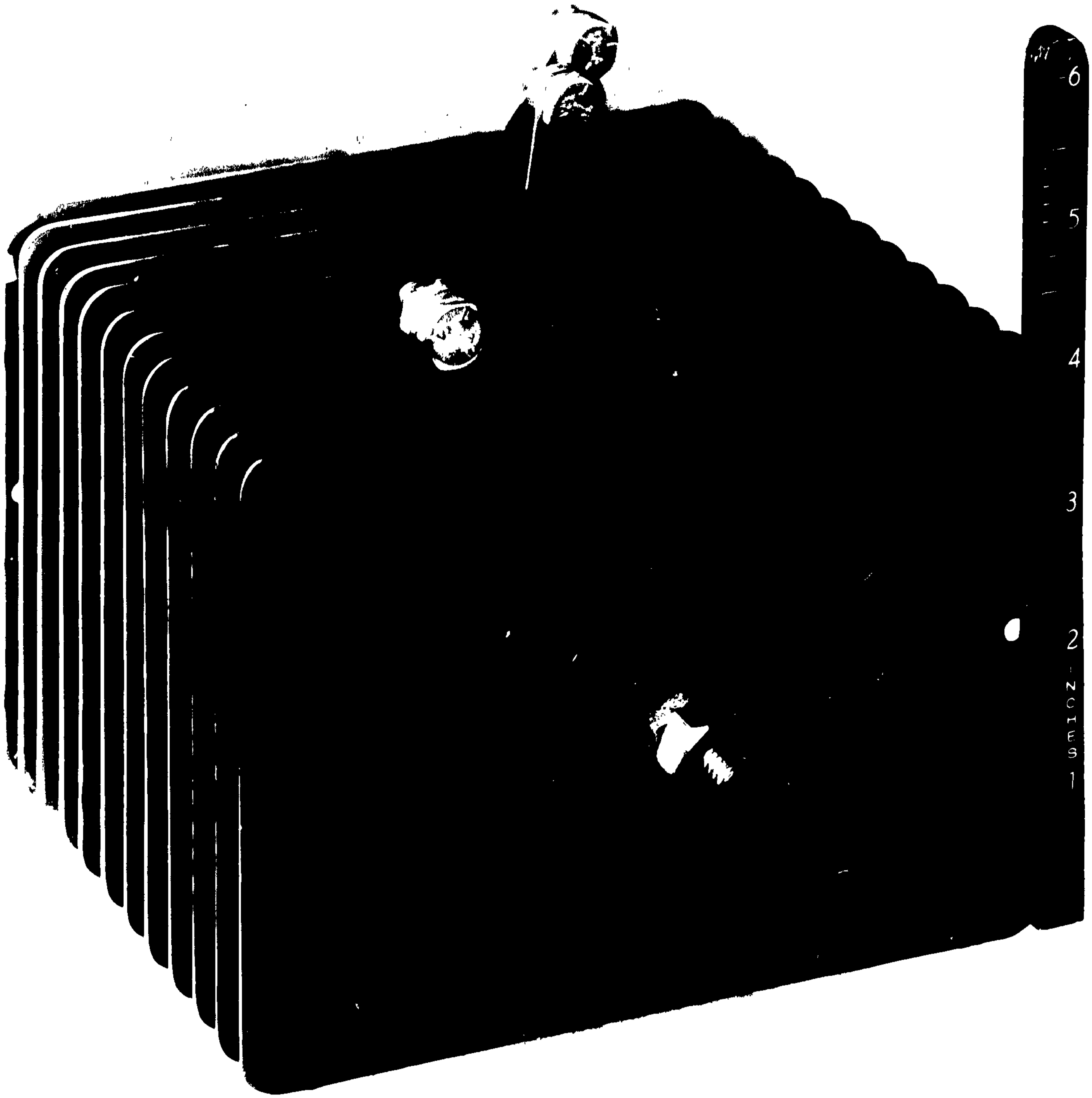
b. Fallout on Adhesive Paper

Time hours	Position From Rectifier	Selenium Fallout
10	2 in.	0.90 x 10^{-3} μg/sq. in./20 hrs.
10	24 in.	0.35 x 10^{-3} μg/sq. in./20 hrs.

*Ventilation - 89 cu. ft./min. in 600 cu. ft. room



ENCLOSURE 2. PLOTS OF SELENIUM CONTAMINATION IN ATMOSPHERE VS. TIME AFTER RECTIFIER BURNOUT



MATERIAL LABORATORY LAB. PROJECT 5319-39

Selenium Rectifier After Burnout

PHOTO L-19459

SUMMARY DATA OF SELENIUM CONCENTRATION ON BURNOUT

Source	Size of Rectifier	Type of Burnout**	Ventilation	Selenium Contamination: Total Evolved Particulate (µg)	Selenium Contamination: Total Evolved Gaseous (µg)	Selenium Contamination: Concentration (µg/l)
Ref. (g)	(1" x 1") (5 plate)	A	No	278-3100	12-145	0.018-0.19
	(1" x 1") (5 plate)	B	No	109-211	7-17	0.007-0.013
MATLAB	(3" x 3") (5 plate)	C	No	410	39	0.024
	(6" x 4") (12 plate)					0.16*
MATLAB (radioactive)	(2" x 2") (5 plate)	C	No	900	2	0.054
	(6" x 4") (12 plate)					0.85*
MATLAB	(6" x 4") (12 plate)	D	Yes	8.4	7.2	0.001

* Calculated Value.

** Burnout A - high overload - instantaneous

B - intermediate overload - sustained

C - stepwise overload

D - stepwise - pulsating overload